Grouting

Dr. Talat A Bader

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What is Grouting?

- Grouting is the injection of pumpable materials into a soil or rock formation to change the physical characteristics of the formation.

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Why Grouting?

- Increased soil strength and rigidity
- Reduced ground movement
- Predictable degree of improvement

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Where Could it Be Used?

- **Grouting Can Prevent:**
  - Collapse of granular soils
  - Settlement under adjacent foundations
  - Utilities damage

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Grouting Design Steps

- Identify underground construction problem
- Establish objectives of grouting program
- Perform special geotechnical study
- Develop initial grouting program
- Develop performance prediction
- Compare with other solutions
- Refine design and prepare specifications

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Grouting Selection Considerations

Important Geotechnical Parameters

- Site specific requirement
- Soil type
- Soil groutability
- Porosity
- Permeability
- Microstratigraphy
- Groundwater

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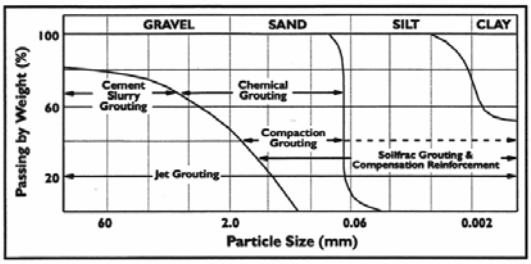
Groutable Soils



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Chemical Grouting

- Structural chemical grouting is the permeation of sands with fluid grouts to produce sandstone like masses to carry loads.
- Water control chemical grouting is the permeation of sands with fluid grouts to completely fill void to control water flow.

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Permeation Grouting Applications

- For lagging operation
- Support of footing
- Grouted tunnel support
- Pit excavation below water
- Grouted cut-off wall
- Grouted pipeline support

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What Chemical Grouts Used?

- Sodium Silicates (GELOC-4)
- Acrylates(AC-400)
- Acrylamides (AM-9, discontinued)
- Polyurethanes (TACCS)
- MC-Silicates

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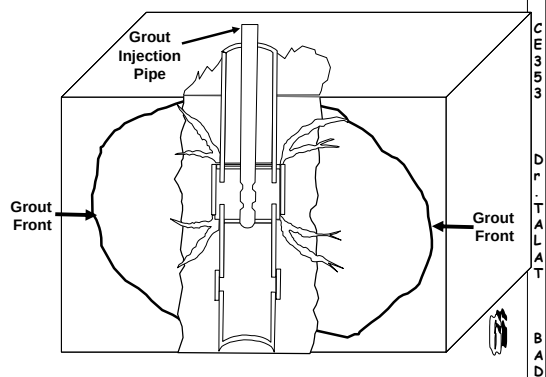

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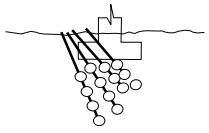
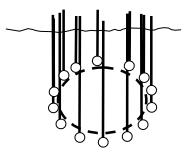
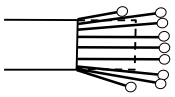
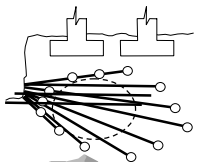
Define Grout Pipe Layout Plan


Fan Array Below Footing


Parallel Array from Surface


Fan Array from Pit


Fan Array from Successive Heading

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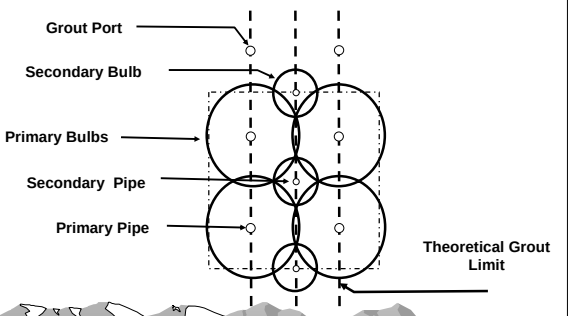
Develop Injection Staging & Sequencing plan



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How to Control Grouting

- Grout hole location and geometry
- Injection rates and pressures
- Grout properties: liquid, transition, set

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injection process measurements (QC)

- What to measure During Injection?
  - Total grout volume at each grout port
  - Injection flow rate vs. time
  - Injection pressure vs. time
  - Microseismic (acoustic) emissions
  - Laboratory injection tests

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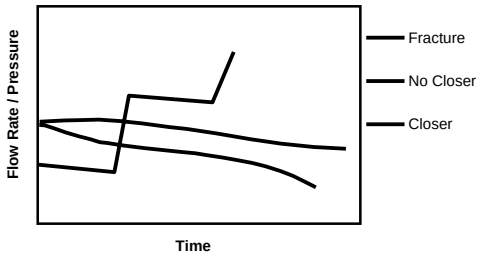
Flow Rate – Pressure Ratio / Time



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Post-Injection Evaluation Tests (QA)

- Is performed to establish the location and boundaries of the grout, and the properties of the grouted soil.
  - Core sampling
  - Inspection pits
  - Pressuremeter Testing (PMT)
  - Standard Penetration Testing (SPT)
  - Reinjection testing
  - Radar profiling
  - Seismic velocity (shear wave) profiling

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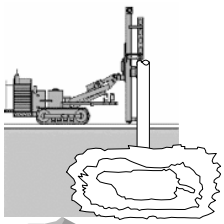
Compaction Grouting (Displacement)

- **injection under relatively high pressure**
- **very stiff, "zero slump" mortar grout**
  - ✓ **to displace**
  - ✓ **compact soils in place**



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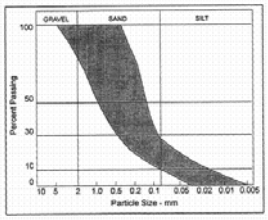
Compaction Grout Materials

- Silty sand
- Cement (Fly-ash)
- Additives (fluidifiers, accelerators)
- Water (up to a maximum of 3" slump)



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Compaction Grouting Applications

- Arrest foundation settlements
- Control soft-ground tunnel settlements
- Provide pre-construction site improvement
- Lift and level slabs and foundations
- Rectify sinkhole problems

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Compaction Grouting Design Steps

- Define geotechnical - structure interaction problem
- Locate comactible soil zones
- Define degree of improvement needed
- Estimate required grout volume displacement
- Plan grout locations and sequence (Test program needed?)

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Procedures

- Special "chop" mixing - 1 to 30 yd^3 per hour
- Force feed piston pumps - to 1000 psi
- "Easy flow" hoses. Friction holds pipes in ground
- Create "grout bulbs" or "piers" to density adjacent ground and arch loads onto piers

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Quality Assurance

- Review pressure/grout volume records
- Review ground and surface displacement records
- Cone Penetrometer Test (CPT)
- Dilatometer Test (DMT)
- Pressuremeter Test (PMT)

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RECOMMENDED READING

1. Brill, G.T. and Darnel, K.E., (1992), "Retention System Using Compaction Grouting in Clay Soils" Proceedings of the ASCE Geotechnical Engineering Specialty Conference: Grouting Soil Improvement and Geosynthetics, Geotechnical Special Publication No. 30, Edited by Roy Borden, Robert D. Holz and Ilan Juran, ASCE, New York, NY, Vol. 2., pp. 791 – 802.
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13. Warner, J., (1982), "Compaction Grouting - The First Thirty Years", ASCE Specialty Conference on Grouting in Geotechnical Engineering, February 1982, New Orleans, Louisiana, pp. 694-707.
14. Graf, E.D., (1969), "Compaction Grouting Technique", Journal of the Soil Mechanics and Foundation Division, ASCE, Vol. 95, No. SM5, Proceedings Paper 6766, pp.1151-1158.

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What is Jet Grouting

- Jet Grouting is Ground Modification system, and is an erosion / replacement system that create an engineered, in situ soil / cement product known as Soilcrete[sm]

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Effectiveness of Jet Grouting

- Soil Type
  - Widest range of soil types
- Performed
  - Around subsurface obstructions
  - In confined spaces
- Effective valuable tool
  - for soft soil stabilization
  - Underpinning
  - excavation of unstable soil
  - Excavation support
  - Control of underground fluids

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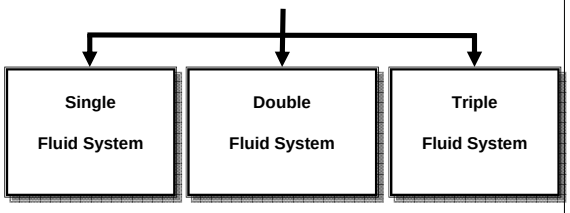
Jet Grouting Systems



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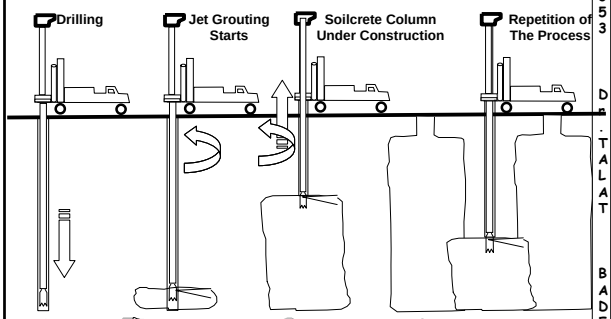
Jet Grout Process



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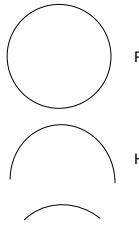
Soilcrete Plan Geometrics



Full Column

Half Column

Partial Column

Soil Erodibility Scale

Highly Erodable

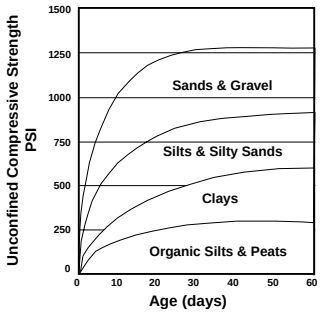
Jet Grouting is an erosion based system, soil erodability plays a major role in predicting geometry quality and production

The geometry & physical properties of the Soilcrete are engineered, the Degree of improvement can be readily predicted

Difficult to Erode

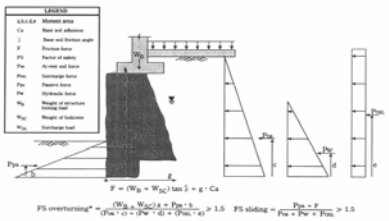
Cobbly Soils
Gravelly Soils
Clean Sands
Loose Silty Sands
Peat's and Organic silts
Dense Silty Sands
Loose Clayey Sands
Low Plasticity Silts
Dense Clayey Sands
Low Plasticity Clays (Soft)
High Plasticity Silts
Low Plasticity Clays (Stiff)
High Plasticity Clays

Typical Soilcreat Strengths



Design Considerations for Underpinning

- Bearing capacity of the system
- Retaining system evaluation for lateral earth pressures and surcharge loads
- Settlement review
- Strength adequacy of the system



Design Considerations for Excavation Support

- What depth is necessary and what shear strength and geometry of Soilcrete will resist the surcharge, soil and water pressure imposed after excavation?
- Are soil anchors or internal bracing necessary?

Design Considerations for Groundwater Control

- What integrity is possible from interconnected Soilcrete elements and how much water can be tolerated through the Soilcrete barrier?

Advantages of Jet Grouting

- Nearly all soil types groutable
- Specific in situ replacement possible
- Designable strength and permeability
- Treatment to specific subsurface locations
- Only inert components
- No harmful vibrations
- Limited working space required
- Any cross-section of soilcrete possible
- Maintenance free
- Safest method of construction
- Ability to work around buried active utilities
- The most effective means of direct underpinning of structures and utilities
- Much faster than alternative methods

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Quality Control/Quality Assurance (QC/QA)

- Sampling of waste materials-conservative relative assessment of in situ characteristics
- Core samples
- Daily report forms-parameters and procedures of treatment

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RECOMMENDED READING

1. Burke, G.K. and Koelling, M.A., (1995), "Special Application for Jet Grouting: Underpinning, Excavation support and Groundwater Control", Proceedings of Canadian Geotechnical Conference, Vancouver, B.C., pp. 90-97.
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- Slurry Grouting is the intrusion under pressure of flowable particulate grouts into open cracks and voids and expanded fractures.

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Slurry Grout Applications

- Rock foundation treatment for dams
- Rock cut-off curtains
- Pressure injected anchors
- Stabilization of gravels and shot rock

Slurry Grout Materials

- Cement
- Clay (Bentonite)
- Sand
- Additives
- Microfine Cement
- Fly ash
- Lime
- Water

Ratios Groutability

For Soils: $N = \frac{(D_{15}) \text{ Soil}}{(D_{85}) \text{ Grout}}$

N > 24: Grouting consistently possible
N < 11: Grouting not possible

$N_c = \frac{(D_{50}) \text{ Soil}}{(D_{85}) \text{ Grout}}$

N_c > 11: Grouting consistently possible
N_c < 6: Grouting not possible

For Rock: $N_R = \frac{\text{Width of fissure}}{(D_{95}) \text{ Grout}}$

N_R > 5: Grouting consistently possible
N_R < 2: Grouting not possible

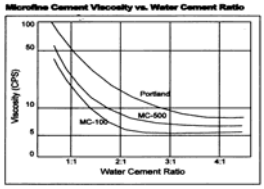
Additional guidelines relating to particular grout types and particle size are:

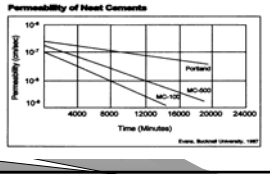
Types I and II Portland cement are suitable for soils coarser than 0.60 mm.

Type III Portland cement is suitable for soils coarser than 0.42 mm.

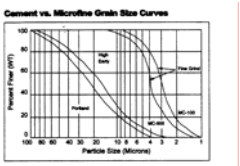
Microfine Cement is …

- Finely ground slag/portland cement that is mixed with a dispersant and large quantities of water for permeation of fine sand and finely cracked rock.





Microfine Cement



Microfine Cement-Depth of Penetration

Grouts	Gravel	Sand		
		Coarse	Medium	Fine
MC-500				
Cement				
MC-100				
MC-500 Sodium Silicate				

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Pumping Cement Grouts

- Steady pressure
- Variable water/cement ratios
- Circulating vs. one-way grout hose systems
- Measuring quantities and pressures: microcomputers
- Uplift

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Slurry Grout Split-Spacing techniques

- Single curtain
- Multiple curtain
- Blanket grouting

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Slurry Grout Quality Control

- Conventional
- Electronic monitoring
- Microcomputer and analysis

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RECOMMENDED READING

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Soilfrac (SM) Grouting

- Soilfrac Grouting is the injection and hydrofracturing with grout slurry of the soil between the foundation to be controlled and the process causing the settlement. Grout slurry is forced into fractures, thereby causing an expansion to take place counteracting the settlement that occurs or producing a controlled heave of the settlement that occurs or producing a controlled heave of the foundation. Multiple injections and multiple levels of fractures create a complementary reinforcement zone.

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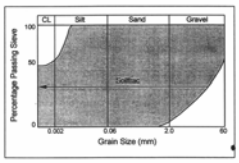
Soil Types

- Because the process requires only that the soil is fractured, Soilfrac may be used in most low permeability soil types ranging from weak rock to clays.



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Application

- Typical applications of the Soilfrac process are:
  - Reduction or reversal of differential settlement
  - Reduction or reversal of total settlement
  - Prevention of the settlement of buildings as tunneling is carried out

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The Soilfrac Process Involves

- Installing grout injection tubes to a predetermined pattern
- Monitoring movements by either precise leveling or the use of special settlement systems
- Injection of grout into sleeves with careful process control to induce compensation movements

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Design of Soilfrac Systems

- Selection and positioning of monitoring systems
- Position of injection tubes
- Initial injection (conditioning)
- Injection during construction to control settlements
- Injection post construction

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Advantages

- The control of settlement is carried out from outside the building and hence there is no disruption to the occupants
- The process can be repeated allowing continued control of settlement (if required)
- Control can be very selective including level changes of varying amounts at specific locations

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Method of Working-Soilfrac

- Sink Shaft
- Install sleeved pipes
- Condition grout
- Inject grout as necessary
- Reinjection unlimited, without redrilling

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Quality Control

- All stages monitored from installation of tubes to actual injection
- Grout mix, injection pressure, volume and pump rate carefully designed and monitored
- Computer monitoring (real time) of structure movements
- Full documentation for every stage

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Monitoring System

- Precise levelling/surveying
- Water level system
- Electro level

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RECOMMENDED READING

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